

INDOOR AIR QUALITY REASSESSMENT

**Lillian M. Jacobs Elementary School
180 Harbor View Road
Hull, Massachusetts 02405**



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
December 2006

Background/Introduction

At the request of David Twombly, Director of Operations, Hull Public Schools (HPS), the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at the Jacobs Elementary School (JES) in Hull, Massachusetts.

A previous IAQ assessment at the JES was conducted in September, 2006. A report was issued by CEH that described conditions observed in the building at that time (MDPH, 2006). At the time of the previous CEH assessment, the JES was in the initial phase of a construction/renovation project with an addition being built adjacent to the existing building (i.e., no construction activities within the building).

On December 4, 2006, a visit to conduct a follow-up assessment at the JES was made by Cory Holmes an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Holmes was accompanied during portions of the assessment by Paula Delaney, Superintendent, HPS, (former) Principal Raymond Joyal, Kathleen Tyrell, Interim Principal, Jeff Costa, PMA Construction, Jodi Trubia, JES Building Liaison, Deborah McCarthy, JES Teacher's Union President, Kathy Bowes, Hull Building Committee and Mr. Twombly. The main objectives of this visit were to examine the integrity of construction barriers erected to prevent occupant exposure to renovation-generated pollutants as well as examining progress toward improving general IAQ by implementing recommendations, previously made by MDPH.

In addition to implementing the majority of MDPH recommendations, several additional measures have been taken by JES staff and HPS officials to improve air quality including;

- The formation of a health and safety committee made up of JES staff and parents.

- The creation of an in-house building liaison position to conduct daily walk-throughs of the building, attend construction meetings and represent the general interest of occupants in regards to construction/renovation activities in the building.
- The creation of a complaint log located in the main office for staff to document health and safety concerns as well as routine maintenance requests (changing ceiling tiles, sink leaks, HVAC repairs, etc.).

It is also important to note that at the time of the CEH reassessment, the modular classroom wing was no longer in use, with no plans in place for reoccupancy by JES students or staff. Occupants from the modular classrooms were relocated to the main JES building and other sites in the HPS system.

Actions on Previous MDPH Recommendations

As mentioned, MDPH staff had previously visited the building and issued a report with recommendations to improve indoor air quality regarding both renovations and general air quality (MDPH, 2006). A summary of actions taken on previous recommendations is included as [Appendix A](#).

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were conducted with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particulate matter with a diameter less than 2.5 micrometers were taken with the TSI,

DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using an HNu, Model 102 Snap-on Photo Ionization Detector (PID).

Results

This JES houses approximately 500 pre-kindergarten through grade 5 students and approximately 55 staff. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million (ppm) in ten of thirty-six areas surveyed, indicating less than optimal air exchange in some areas. It is important to note however, that all classrooms had operating univents with the exception of two that were deactivated due to heat complaints. Exhaust vents in several classrooms were found obstructed by classroom items and/or not operating (Table 1).

It is important to note that none of these systems were activated during the September 2006 assessment. IAQ has improved since that time due to increasing mechanical airflow, removing (the majority of) obstructions from classroom supply and exhaust vents and supplementing mechanical ventilation by opening windows when possible. Additional efforts in these areas should result in enhancing air quality.

With that said, better coordination is needed between building occupants and the maintenance department to identify and correct ventilation issues. For example, instead of deactivating univents due to overheating, the thermostat should be adjusted (or repaired) to

lower heat. In addition, efforts should be improved by building occupants and maintenance staff to remove classroom items from the vicinity of univents and exhaust vents to facilitate airflow.

The art closet is reportedly used as a temporary office. The closet has no means of mechanical supply air or openable windows but has an exhaust vent only. At the time of the assessment the exhaust vent was not operating. CEH staff recommended reactivating the exhaust vent *and* either undercutting the door (1 to 2-inches) or installing a passive door vent to allow for air exchange.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (BOCA, 1993; SBBRS, 1997). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health

status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see [Appendix B](#).

Temperature readings during the assessment ranged from 67° F to 75° F, which were within or slightly below the MDPH comfort guidelines. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. As mentioned previously, two univents were deactivated due to heat complaints. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements during the assessment ranged from 21 to 38 percent, which were below or close to the lower end of the MDPH recommended comfort range in the areas surveyed. The MDPH recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As previously mentioned, the modular classroom wing was closed to occupancy at the time of the MDPH reassessment. This decision is supported by the MDPH based on issues of concern identified in the previous MDPH assessment including water penetration, mold growth and lack of ventilation in concert with additional evidence of mold growth that occurred subsequent to the MDPH visit (OASIS, 2006).

On October 21, 2006, the HPS contacted OASIS, Environmental Contracting Services, Inc., (OASIS) to investigate suspected mold growth in wall cavities of modular classrooms 3, 4. The modular office area and the plywood enclosed walkway connected to the original building were also tested during this investigation. Analytical results by OASIS determined that the predominate mold species found inside the wall cavity had not become airborne, however opening the wall without proper containment created a pathway for mold spores to enter the occupied areas (OASIS, 2006). Please note that the US Environmental Protection Agency (USEPA) recommends the use of personal protective equipment during removal of building materials, due to the fact that such removal can lead to the release of large quantities of mold spores into the interior environment. In the case of hidden mold investigation, the USEPA recommends considering hiring an experienced professional (USEPA, 2001).

Testing results from OASIS indicated slightly elevated concentration of spores in classroom 3, 4, the office area and plywood hallway connecting the modular classrooms to the main building (OASIS, 2006). OASIS also determined a lack of cross ventilation in the protective wooden skirts creating a void space where moisture was trapped beneath the modular classrooms. In addition, wet rolled up sections of carpeting were found in the crawlspace, which likely contributed to odors detected in the building. Based on these findings OASIS recommended full remediation of water damaged materials using containment measures and negative air filtration (OASIS, 2006). At the time of the CEH reassessment, remediation activities had not been conducted likely due to the modular classroom wing being vacated.

In respect to the main building, some areas on both the first and second floor had water-damaged ceiling tiles several of which were identified during the last MDPH assessment (Table

1). Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Renovations and Other IAQ Evaluations

As previously mentioned, this most recent assessment coincided with the commencement of construction inside the building. CEH staff inspected construction barriers to identify and reduce/prevent pollutant pathways. Floor-to-ceiling construction barriers were erected due to the removal of asbestos floor tiles in rooms being phased for renovation, which requires strict adherence to state and federal regulations involving containment and isolation methods. The solid barriers consisted of wood frames and gypsum wallboard that were sealed at the edges with duct tape and/or caulking (Pictures A-1 through A-5). The interior of the solid barriers (i.e., the construction side) were sealed floor to ceiling with polyethylene plastic and tape or mastic. In addition, CEH staff recommended sealing doors that traverse a common wall with construction areas with polyethylene plastic and duct tape on the occupied side as a secondary barrier (Pictures A-1 and A-5).

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants.

Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM_{2.5}) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, CEH staff obtained measurements for carbon monoxide and PM_{2.5}.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building

Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM₁₀). According to the NAAQS, PM₁₀ levels should not exceed 150 microgram per cubic meter ($\mu\text{g}/\text{m}^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM_{2.5} standard requires outdoor air particle levels be maintained below 35 $\mu\text{g}/\text{m}^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM₁₀ standard for evaluating air quality, MDPH uses the more protective proposed PM_{2.5} standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM_{2.5} concentrations were measured at 18 $\mu\text{g}/\text{m}^3$ (Table 1). PM_{2.5} levels measured in occupied areas of the school ranged from 12 to 35 $\mu\text{g}/\text{m}^3$, which were below the NAAQS of 35 $\mu\text{g}/\text{m}^3$ in all but one area (Table 1). Classroom 32 was equal to the NAAQS. Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited

to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Indoor TVOC concentrations were ND (Table 1). An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were also ND. Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling.

Finally, reportedly due to limited space during renovations, several photocopiers, a Risograph that uses liquid toner, several computers and a lamination machine were temporarily relocated to an unventilated interior room. Laminating machines and photocopiers can give off waste heat and irritating odors. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992). At the time of the assessment CEH staff recommended relocating the equipment to alternate areas and/or instructing staff to reduce time spent in the room during photocopying activities.

Conclusions/Recommendations

The relocation of students and staff from the modular classroom wing has eliminated exposure opportunities associated with mold in these areas; however concerns remain due to the main building being connected to the modular wing via a hallway. At the time of the reassessment, CEH staff recommended sealing the modular classrooms from the main building.

The main building remains under construction, which can lead to potential exposures to construction/renovation-generated pollutants if control/containment measures are not adequate. A number of issues indicated in the previous MDPH report have been observed in other elementary school environments (clutter, dust control, building maintenance), particularly those built several decades ago. If considered individually, these issues present conditions that can degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require continued diligence by all parties involved with daily/routine maintenance and/or specific alterations to the building structure involving construction and renovations.

In view of the findings at the time of the reassessment, the following recommendations are made to further improve indoor air quality:

1. Continue to implement all applicable recommendations listed in the previous MDPH report (MDPH, 2006).
2. Encourage staff to report environmental concerns and/or document routine maintenance request (changing ceiling tiles, sink leaks, HVAC repairs, etc.) in the log located in the main office.

3. Continue efforts to educate staff concerning the importance of operating the ventilation system appropriately and keeping ventilation vents unobstructed.
4. Continue to restrict the use of modular classrooms.
5. Erect a barrier similar to those in construction areas to seal hallway between modular classroom wing and main building.
6. Continue with plans to make repairs to exhaust vents that are on the repair list. The status of items on this list should be shared with the building liaison who, in-turn should keep maintenance staff informed of any additional items in need of repair/adjustment identified during daily walkthroughs and input from JES staff.
7. Work with occupants of classrooms 23 and 27 to mitigate heat issues with unit ventilators and/or thermostatic controls.
8. If the art closet is to remain in use as an office, reactivate the exhaust vent *and* either undercut the door (1 to 2-inches) or install a passive door vent (similar to a restroom) to allow for air exchange.
9. Overall clutter should be reduced in the building. Consider renting a mobile storage unit and/or dumpster to encourage staff to remove/discard infrequently used items in classrooms to improve cleaning capabilities.
10. Employ the use of walk-off mats at all entrances to help contain dirt, dust and debris tracked in from the outside.
11. Consider installing carbon monoxide detectors near construction barriers.
12. Store cleaning products and chemicals properly and keep out of reach of students. Refrain from using products not approved by school administration.

13. Clean air diffusers, exhaust/return vents and personal fan blades periodically of accumulated dust.
14. Relocate lamination machine, Risograph and photocopiers to alternate areas or instruct staff to reduce time spent in the teacher's room during photocopying activities.
15. For information on mold/remediation consult "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency (US EPA, 2001). This document can be downloaded from the US EPA website at:
http://www.epa.gov/iaq/molds/mold_remediation.html.
16. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: <http://www.epa.gov/iaq/schools/index.html>.
17. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://mass.gov/dph/indoor_air.

References

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Location: Jacobs Elementary School

Indoor Air Results

Address: 180 Harbor View Road, Hull, MA

Table 1

Date: 12/4/06

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background		38	49	340	ND	ND	18				Partly cloudy, light snow in am, winds NNW 10-15 mph
Computer lab	1	67	37	571	ND	ND	28	N	Y	Y	Dusty vents, TB, PF
Library	1	69	31	518	ND	ND	24	Y	Y	N	
Testing room	0	70	38	695	ND	ND	24	N	Y	Y	1 CT, dusty vents, spray cleaning products
41	1	70	35	693	ND	ND	15	Y	Y	Y	11 occupants gone approx 1 min, exhaust vent-off
40	4	71	31	572	ND	ND	16	Y	Y	Y	Exhaust-off
11	13	71	30	747	ND	ND	16	Y	Y	Y	DO, 1 CT-corner, 2 CT-interior wall
13	19	69	29	641	ND	ND	21	Y	Y	Y	1 CT-corner, spray cleaning products, DO

ppm = parts per million

µg/m3 = micrograms per cubic meter

AD = air deodorizer

AP = air purifier

aqua. = aquarium

AT = ajar ceiling tile

BD = backdraft

CD = chalk dust

CP = ceiling plaster

CT = ceiling tile

DEM = dry erase materials

design = proximity to door

DO = door open

FC = food container

GW = gypsum wallboard

MT = missing ceiling tile

NC = non-carpeted

ND = non detect

PC = photocopier

PF = personal fan

plug-in = plug-in air freshener

PS = pencil shavings

sci. chem. = science chemicals

TB = tennis balls

terra. = terrarium

UF = upholstered furniture

VL = vent location

WD = water-damaged

WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred

600 - 800 ppm = acceptable

> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F

Relative Humidity: 40 - 60%

Location: Jacobs Elementary School

Address: 180 Harbor View Road, Hull, MA

Indoor Air Results

Date: 12/4/06

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
15	19	72	28	657	ND	ND	12	Y	Y	Y	TB, DO, exhaust vent-off
17	21	70	30	749	ND	ND	17	Y	Y	Y	DO, exhaust vent-off
19	20	70	27	587	ND	ND	16	Y	Y	Y	Exhaust vent-off, window open
18	17	70	28	630	ND	ND	27	Y	Y	Y	Dusty fan
16	16	68	26	500	ND	ND	24	Y	Y	Y	Cleaning product odor-table washed, window open
14	22	70	28	678	ND	ND	19	Y	Y	Y	Dusty fan
12	1	70	28	561	ND	ND	12	Y	Y	Y	Cleaning products, 19 occupants gone, PF, 2 CT, porous items under sink
10	4	69	28	605	ND	ND	12	Y	Y	Y	

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									Supply	Exhaust	
23	13	74	32	987	ND	ND	25	Y	Y	Y	UV-deactivated-heat issues, plant on UV
25	17	70	26	810	ND	ND	23	Y	Y	Y	TB, items on UV, dusty exhaust vent-partially obstructed
27	17	69	30	1188	ND	ND	26	Y	Y	Y	UV-off-heat complaints, DO
29	13	72	33	1077	ND	ND	18	Y	Y	Y	Exhaust-weak, accumulated classroom items, cleaning products, PF
31	16	71	25	727	ND	ND	30	Y	Y	Y	Items on UV, spray bottle on sink, TB, PF
33	16	69	27	770	ND	ND	27	Y	Y	Y	DO, exhaust vent-off, containment wall for renovations
34	18	70	29	770	ND	ND	30	Y	Y	Y	Plants on UV, exhaust vent- off/partially obstructed
32	6	72	29	898	ND	ND	35	Y	Y	Y	Flowering plant near UV, TB, exhaust vent-off/partially obstructed

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									Supply	Exhaust	
30	16	72	28	953	ND	ND	22	Y	Y	Y	DO, exhaust near hallway door
28	17	71	29	941	ND	ND	28	Y	Y	Y	Spray cleaning product on sink, DO, PF
26	35	72	32	1288	ND	ND	28	Y	Y	Y	Double occupied due to indoor recess
24	15	71	30	979	ND	ND	24	Y	Y	Y	Exhaust vent behind open door, cleaning product on counter
Cafeteria A	0	73	25	594	ND	ND	31	N	Y	Y	TB, ceiling fan-on
Stage	5	73	25	623	ND	ND	27	N	N	Y	PF
Cafeteria B	20	74	24	567	ND	ND	33	Y	Y	Y	TB, windows open
Cafeteria D	18	74	24	567	ND	ND	25	Y	Y	N	
Cafeteria C	16	75	27	608	ND	ND	29	Y	Y	N	

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									Supply	Exhaust	
Speech	4	73	29	863	ND	ND	24	Y	N	Y	Exhaust-off, TB
Reading	0	74	24	565	ND	ND	25	Y	Y	Y	Exhaust-off
Gym	17	73	21	458	ND	ND	30	Y	Y	Y	
Main office	4	74	26	633	ND	ND	22	Y	N	N	

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DO = door open

FC = food container

GW = gypsum wallboard

MT = missing ceiling tile

NC = non-carpeted

ND = non detect

PC = photocopier

PF = personal fan

plug-in = plug-in air freshener

PS = pencil shavings

sci. chem. = science chemicals

TB = tennis balls

terra. = terrarium

UF = upholstered furniture

VL = vent location

WD = water-damaged

WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
 600 - 800 ppm = acceptable
 > 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
 Relative Humidity: 40 - 60%